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Assessment of Elemental Composition of Rice Husk from Darma Rice Mills, Katsina State, Nigeria

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ABSTRACT
Rice husk (RH), an abundant agricultural by-product obtained during rice milling, has attracted increasing attention due to its potential applications in agriculture, environmental remediation, and industrial production. However, its elemental composition may change depending on environmental conditions, cultivation practices, and processing methods, leading to the possible contamination with toxic heavy metals that pose environmental and health concerns. This study investigated the elemental composition of rice husk obtained from Darma Rice Mill, Katsina State, Nigeria, using Energy Dispersive X-ray Fluorescence (EDXRF) spectroscopy. The rice husk samples were collected, prepared, and analyzed to determine the concentration of major and trace elements. The results revealed the presence of several elements at varying concentrations, with silicon (Si) identified as the dominant beneficial element due to the naturally siliceous nature of rice husk. Other essential elements such as potassium (K), calcium (Ca), iron (Fe), sulfur (S), and aluminum (Al) were also detected. However, lead (Pb) recorded an exceptionally high concentration and exceeded the permissible limits recommended by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), indicating possible environmental contamination. Trace elements including niobium (Nb), tungsten (W), tin (Sn), tantalum (Ta), nickel (Ni), copper (Cu), and zinc (Zn) were detected at relatively low concentrations. The findings highlight the potential environmental and public health risks associated with improper reuse or disposal of contaminated rice husk and emphasize the need for continuous monitoring, proper management, and treatment strategies to minimize heavy metal contamination.

INTRODUCTION

The consumption of rice is continuously increasing globally. It has been predicted that by the year 2035, it will reach about 116 million tonnes, signifying an increase in demand of 130% from 2010, and one-third of this increase will be from Nigeria (Gaima et al., 2022). In Nigeria, rice has a consumption per capita of 32 kg, indicating a 4.7% increase in the past decade, making the total consumption 6.4 million tons in 2017 as against 3.7 million tons produced per year (Bodie et al., 2019). Nigeria is the highest producer and consumer of rice in West Africa and is among the leading importers of rice in the world.

Rice husk (RH) is the major pollutant in rice milling environments. It is the outer hard protective shell surrounding the paddy grain, accounting for about 20% of its weight (Nnadiukwu et al., 2023). It is composed of hard materials, including opaline silica and lignin, and has been used as a constituent in building materials, fertilizer, insulation, and fuel. Current world rice production is estimated at 700 million tons, with rice husk constituting about 20% of the weight of rice. Its composition is approximately 50% cellulose, 25-30% lignin, 15-20% silica, and 10-15% moisture (Singh, 2018).

The disposal of rice husk is a major challenge, often leading to environmental pollution when discharged into water bodies or burned in the open air (Taiwo et al., 2024). The elemental composition of rice husk can vary significantly depending on environmental factors, agricultural practices, and soil conditions. Some rice husks may accumulate toxic elements such as lead (Pb), cadmium (Cd), or arsenic (As), which could pose environmental or health risks if not properly managed (Adamu & Salihi, 2025). Therefore, the assessment of the elemental composition of rice husk is essential for determining its safety for reuse and understanding its environmental implications.

However, several studies in Nigeria have assessed the elemental or chemical composition of rice husk and rice husk ash, providing a useful basis for site specific investigations. For instance, Adamu et al. (2023) evaluated the chemical composition of rice husk from different local government areas in Bauchi State using X ray fluorescence (XRF), reporting major oxides such as SiO_2, K_2O, CaO, MnO, Fe_2O_3, and several trace metal oxides. Ayinde and Bello (2025) characterized rice husk ash from five large rice producing companies in Nigeria and recorded SiO_2 contents above 70%, highlighting its suitability as a pozzolanic material for construction applications. Similarly, work on rice husk ash and clay soil along the River Niger–Lokoja axis indicated silica levels around 45–46%, reflecting the influence of combustion conditions and local feedstock (Nathan et al., 2016). More recently, an analysis of the morphological and elemental composition of rice–bean–groundnut husk mixtures in Nigeria showed Si, K, P, Ca, and Mg as dominant elements, underscoring the potential of these agro wastes for industrial and agricultural uses (Idris et al., 2024).

Darma Rice Mill, a modern large-scale rice processing company in Katsina State, provides a suitable study area for this assessment. This research aims to fill the knowledge gap regarding the elemental composition of rice husk from this specific location, as no comprehensive study has been carried out there. The study aims to determine the elemental composition of rice husk using Energy Dispersive X-ray Fluorescence (EDXRF) and to compare the results with WHO/FAO standard permissible limits.

MATERIALS AND METHOD

Study Area and Sample Collection

The study area for this research is Darma Rice Mill, a major rice processing company located at Tafawa Balewa Way, along the Katsina-Dutsin-Ma Road in Katsina Local Government Area, Katsina State, northern Nigeria. Katsina State is situated in the north-western region of Nigeria, covering an estimated land area of about 23,938 km^2, and lies between latitudes 11°07'49" N and 13°22'57" N, and longitudes 6°52'03" E and 9°09'02" E.. Rice husk samples were collected from the milling site in October 2025 using a polythene bag, with proper labeling using masking tape.

Sample Preparation and Analysis

The rice husk sample was prepared for analysis by first grinding it into a fine powder using a mortar and pestle. Two grams of the powdered sample were weighed and placed into a sample holder with a polypropylene base, covered with cotton wool to prevent spillage. The sample was then analyzed using an Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer (Thermo Fisher Scientific) at central laboratory, Umaru Musa Yar'adua University, Katsina. The analysis was conducted in a vacuum for 10 minutes. The instrument was calibrated using a biological calibration method.

Data Analysis

The XRF concentration values, generated in parts per million (ppm), were converted to percentage (%) concentration using the formula (Igwebike-Ossi, 2017):

$$X\% = \frac{Xppm}{10000} \quad (1)$$

The percentage of element is obtained using the relation (Odesina, 2008):

$$Masspercent = \frac{massofsolute}{massofsolution} \times 100\% \quad (2)$$

RESULTS AND DISCUSSION

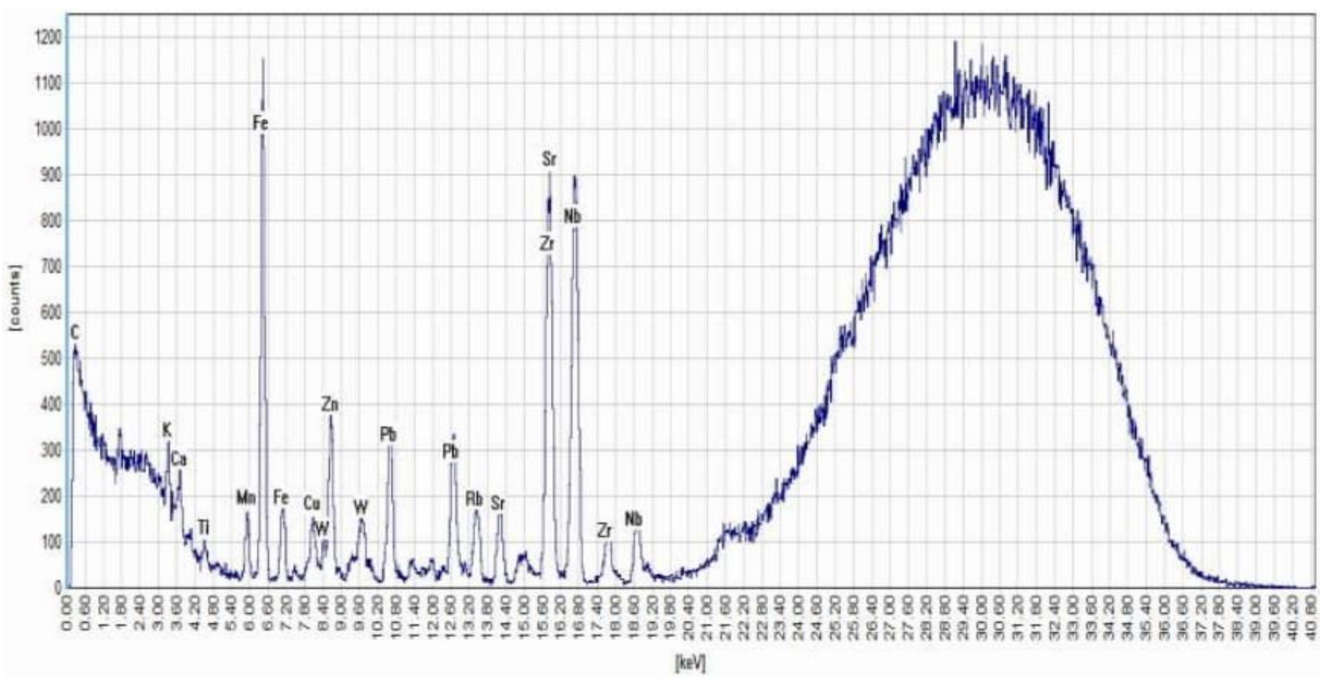
Elemental Composition

The EDXRF analysis revealed the presence of 23 elements (both major and trace elements at varying concentrations) in the rice husk sample. The results, presented as percentage concentrations, are summarized in Table 1. The spectral data and concentration levels are also shown in Figures 1a and 1b.

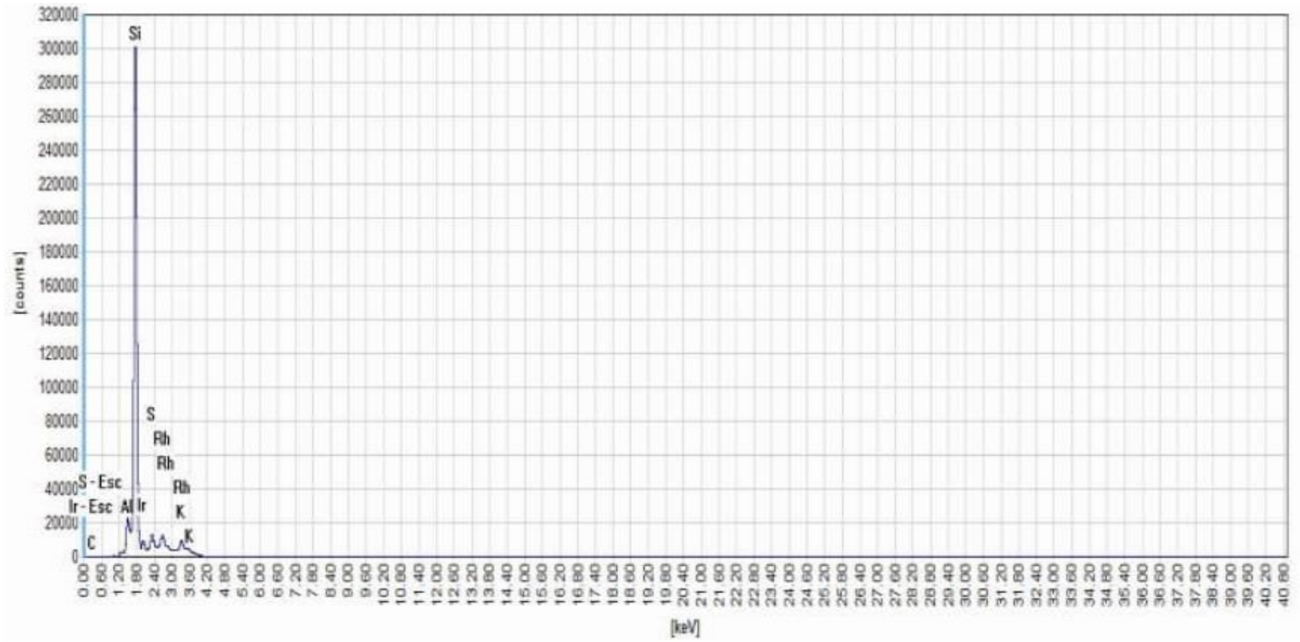
Table 1: Elemental Components (in %) of Rice Husk from Darma Rice Mill Katsina, Katsina State

S/N	Elements	Percentage Concentration (%)
1	Pb	42.91
2	Si	22.39
3	Nb	9.54
4	Ca	4.66
5	W	4.41
6	K	4.92
7	Fe	1.97
8	S	1.29
9	Sn	1.56
10	Ta	1.23
11	Ni	0.18
12	Al	1.43
13	Na	0.64
14	Mg	0.41
15	P	0.70
16	Mn	0.55
17	Rb	0.05
18	Sr	0.04
19	Br	0.01
20	Cl	0.94
21	Cu	0.02
22	Zn	0.15
23	Cr	0.0067

However, the results also confirm that bismuth (Bi), vanadium (V), arsenic (As), and silver (Ag) were not detected. The wide variation in elemental concentration may be due to the differences in elemental uptake from soil, environmental exposure, and possible anthropogenic influences during rice cultivation and processing (Gupta et al., 2025).



(a)



(b)

Figure 1a and 1b: Concentration Level of Elements in Darma Rice Husk

Dominant and Major Elements

From Table 1, it is seen that lead (Pb) was detected with the highest concentration (42.90%), which is exceptionally high compared to international safety standards. However, Pb is a toxic heavy metal with no known biological function in humans. Its presence at this high level may be linked to contaminated agricultural soil, use of agrochemicals, atmospheric deposition, or contamination during milling (Bello et al., 2019). According to the FAO/WHO (2025), the permissible limit of lead in food materials is typically ≤ 0.2 – 0.3 mg/kg, indicating that the observed concentration far exceeds safe limits as shown in Table 2.

Silicon (Si), with a concentration of 22.38%, was the second most abundant element. This high silicon content is expected, as rice husk is naturally rich in silica due to its structural role in rice plants. This finding agrees with previous studies that identify rice husk as a major natural source of silica (Yuan et al., 2024; Islam et al., 2024). Other elements such as niobium (Nb = 9.54%), potassium (K = 4.92%), calcium (Ca = 4.66%), and tungsten (W = 4.41%) were also found in relatively high concentrations.

Essential elements like iron (Fe = 1.97%), aluminum (Al = 1.49%), sulfur (S = 1.29%), tin (Sn = 1.56%), and tantalum (Ta = 1.23%) were detected at moderate concentrations. Elements such as chlorine (Cl = 0.94%), phosphorus (P = 0.70%), sodium (Na = 0.64%), magnesium (Mg = 0.41%), and manganese (Mn = 0.55%) were present in low to moderate concentrations and are commonly associated with agricultural soils and plant tissues.

Trace and Toxic Elements

Trace elements such as copper (Cu = 0.0166%), nickel (Ni = 0.18%), zinc (Zn = 0.15%), chromium (Cr = 0.00067%), rubidium (Rb = 0.0548%), strontium (Sr = 0.0359%), and bromine (Br = 0.0147%) were detected in very low concentrations. The values obtained for these elements are within WHO/FAO permissible limits, suggesting minimal health risk from these elements (FAO/WHO, 2025). Highly toxic elements such as arsenic (As), silver (Ag), bismuth (Bi), and vanadium (V) were not detected, indicating limited industrial contamination in the milling site.

Comparison with WHO/FAO Standards

A comparison of key potentially toxic elements with WHO/FAO permissible limits is shown in Table 2. This comparison clearly shows that lead (Pb) is the only element that exceeds permissible limits by a very large margin, while other potentially toxic elements remain within acceptable safety thresholds (FAO/WHO, 2025).

Table 2: Comparison with WHO/FAO Permissible Limits (FAO/WHO, 2025)

Elements	Concentration (%)	WHO/FAO permissible limit	Remark
Pb	42.90	≤0.2–0.3 mg/kg	Far above limit
Cu	0.0166	≤10 mg/kg	Within limit
Ni	0.18	≤1.5 mg/kg	Within limit
Zn	0.15	≤60 mg/kg	Within limit
Cr	0.0067	≤2.3 mg/kg	Within limit
As	0	≤0.2 mg/kg	Not detected

Toxicological and Health Implications

The extremely high concentration of lead (Pb) observed in the rice husk sample raises serious environmental and public health concerns. Chronic exposure to lead has been associated with neurological damage, kidney dysfunction, reduced cognitive development in children, and cardiovascular disorders in adults (Flora et al., 2012; Collin et al., 2022). Although rice husk is not directly consumed, its reuse as animal feed, fertilizer, or compost could introduce lead into the food chain and surrounding environment. The dominance of lead overshadows the presence of beneficial elements and necessitates regular monitoring and potential remediation strategies.

CONCLUSION

This research work, reveals the concentration of elemental composition of rice husk obtained from Darma rice mill, katsina state, Nigeria using EDXRF technique. The analysis revealed the presence of both essential and trace elements, with silicon occurring as the dominant component, alongside other beneficial elements such as calcium, potassium, iron, and sulfur. These elements highlight the potential usefulness of rice husk for agricultural and industrial applications. The detection of lead (Pb) at a concentration above recommended WHO/FAO limits indicates possible environmental contamination and poses potential health and environmental risks. This suggests that rice husk from Darma rice mill should be properly monitored and treated before reuse or disposal, while rice husk from Darma rice mill contains valuable elemental constituents, adequate environmental control and regular monitoring are necessary to minimize the risks associated with toxic heavy metal contamination. The nobility of this finding is that, it clarifies the elemental composition of Darma rice husk sample with its characteristic futures, to the best of our knowledge first of its kind in Katsina state.

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